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MOŻLIWOŚCI WYKORZYSTANIA CIEPŁA ODPADOWEGO I ENERGII GEOTERMALNEJ DO ODŚNIEŻANIA I ODLADZANIA - KONCEPCJE I PROBLEMY

HOW TO USE WASTE HEAT AND GEOTHERMAL ENERGY FOR DE-SNOWING AND DE-ICING IN POLAND - CONCEPTS AND PROBLEMS

STRESZCZENIE

Instalacje cieplne służące do odladzania nawierzchni drogowych są kosztowne na etapie inwestycyjnym, ale przyczyniają się do poprawy bezpieczeństwa ruchu drogowego. Jeśli w pobliżu znajdują się kopalniane zakłady wodne, to energię cieplną do odladzania można uzyskać niemal za darmo. W niniejszym opracowaniu przedstawiono propozycje wykorzystania w kilku obiektach ciepła wód kopalnianych oraz ciepła odpadowego z instalacji przemysłowych.

ABSTRACT

Heat instalments used for de-icing of roads are costly at the stage of investment but beneficial in terms of safety. If plants employing mine waters are close to roads, thermal energy for de-icing can be obtained at very little cost; this factor is crucial in the present study. A scheme for the use of mine waters and the waste heat from industrial instalments is described.

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INTRODUCTION

Cheap and clean waste heat energy, commonly available in industrial areas, can be directly utilised in instalments for de-snowing and drying of roads, squares, sport routes, stadiums and pedestrian crossings. This should increase safety and comfort in public areas from late autumn to spring time. Other advantages of this approach lie in its convergence with environmentally-friendly solutions applied in the transportation industry and the possibility of elongating the season for outdoor sports events.

A de-icing system at road junctions, overpasses and roundabouts increases the efficiency of braking and driving in icy conditions. The roads where de-icing and drying techniques are applied then do not need to be treated with salt, which has a favourable effect on the environment. Other advantages are that lamp-posts and lanterns do not corrode, and the life of metal elements of bridges and overpasses is considerably prolonged. Drying of bus-stop areas increases the ease of transportation in big cities and reduces the risk of damage to footwear from the saline snow. Stadiums with de-iced surfaces can be hired for various events that cannot be organised elsewhere during cold weather. An example of such a solution is the Olympic football stadium in Munich.

EXISTING SOLUTIONS

Instalments for de-snowing and de-icing of roads and pedestrian routes are in use in numerous countries, most commonly in Japan (about 1000, with new ones still under construction). Based on various heat sources, they are all treated as an important element of the communication system both within the cities and beyond them. They have been installed in response to the accidents and problems with car and pedestrian movements that occur under icy conditions. Locations that are most likely to be de-iced are: surfaces at 8% inclination, road junctions, tunnel inlets and outlets, squares and pavements with intensified pedestrian movement, passages for pedestrians, parking areas and even park paths (Fig. 1).

The most common, however expensive in exploitation is a heating system with high-voltage current through resistivity cables located in the subgrade of roads, pavements, and - most often - stairs.

Heating with hot liquid is also common system; its installation is rather more expensive than exploitation. There is a variety of heat sources:

- Traditional systems base on oil boilers, gas boilers or warm water from deep wells.
- The Gaia system (Morita & Tago 2000), employs indirectly the heat of the Earth. The heat is collected from

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wells about 150 m deep by a concentric-pipe heat exchanger (Morita et al. 1992). The liquid from the heat exchanger is transmitted to a heat pump, from which it goes to the subsurface coils (Fig. 2). After the winter season is over, both water loops are interconnected automatically. The liquid is pumped through the coils under the road, from where the solar heat is absorbed and passed to waters in the wells (Fig. 2).

- Unconventional solutions: in some cases high-yield heat pipes are used. The de-iced surface is supplied with heat coming from a hot-water pipeline, instead of traditional coils with flowing water.
- Direct use of the heat of the Earth. The de-icing systems in Iceland and in Oregon, USA where the temperature reaches 100 °C at 100 m depth, are supplied with thermal waters of very high initial temperature, reduced in the cascaded system of heat delivery. The last element of the cascade is usually the de-icing system. Thus, here we are dealing with a kind of waste heat (below 20 °C) (Brown 1999, Boyd 1999).

Scheme of a de-icing system employing a coil with warm water (Fig. 2)

The system for surface de-icing is composed of the following elements:
1 - source of heat
2 - surface heater
3 - pipes supplying the heat energy carrier, pumps, valves, controls
4 - electrical supply for controls
5 - electrical current generator (for emergencies).

In most cases, water of natural temperature equal to approximately 20 °C is used as a carrier and source of heat; the lower temperature limit for water directly used for de-icing is approximately 10 °C. The return water may be a few degrees centigrade (after JGD). Cooler water is heated in gas or oil boilers installed near the de-iced structures and roads, and pavements (Fig. 3). In cities, boilers are situated underground. Only the control box, catalyst and exhaust chimney are located on the surface (Fig. 4)

Table 1. Comparative investment costs (after Morita) of different systems for de-icing of 1300 m^2 of surface (US$ x 1000)[1)]
Tabela 1. Porównanie kosztów inwestycyjnych (wg. K. Morita) różnych systemów odladzania dla pow. 1300 m^2.

	Heat pump water/glycol (Gaia system)	Heat pump air/glycol	Oil boiler/water	Electric resistance cables	Waste heat (in Poland)[2)]
Surface, additional cost	257	257	257	257	**-**
Heaters in the road	168	177	164	180	**80**
Well with exchanger	437	-	-	-	**-**
Heat pump	209	470	-	-	**-**
Oil boiler	-	-	262	-	**-**
Electric lead	-	63	-	176	**-**
Waste water supply	-	-	-	-	**15**
Control system	78	-	-	20	**15**
Pipes and cables	103	79	120	31	**5**
Masonry	14	13	0	30	**5**
Inspection	255	150	220	110	**15[3)]**
Total	**1521**	**1209**	**1023**	**804**	**130[4)]**
Unit cost (m^2)	1.2$	0.9$	0.8$	0.6$	**0.05[4)]**

1) calculated cost of work and materials; 100 Y = 1 US$
2) estimated cost equal to 1/2 cost in Japan, newly built road
3) head of construction x 1/2 year
4) expected costs after work instruction, and profesional contractors are employed

Table 2. Comparative costs (after K. Morita) of exploitation of different systems for de-icing of 1300 m^2 of surface per year (US$ x 1000) [1)]
Tabela 2. Porównanie rocznych kosztów eksploatacyjnych różnych systemów odladzania dla pow. 1300 m^2 (wg. K. Morita)

	Heat pump water/glycol (Gaia system)	Heat pump air/glycol	Oil boiler/water	Electric resistance cables	Waste heat (in Poland)[2)]
Electrical energy or fuel	9.1	16.5	17.7	33.8	**1.0[3)]**
Maintenance	2.5	2.5	3.0	2.5	**1.25**
Total	**11.6**	**19.0**	**20.7**	**36.3**	**2.25[4)]**
Unit cost (m^2)	8.9$	14.6$	15.9$	28.0$	**1.7$**

1) calculated cost of work and materials; 100 Y = 1 US$
2) estimated cost equal to 1/2 cost in Japan
3) estimated cost of electrical energy for driving a circuit pump (20kWx500 h=10 000kWh).

Fig. 1. The result of de-icing installation work on a part of road
Ryc. 2. Wynik funkcjonowania instalacji odladzania fragmentu jezdni

A coil located about 8 cm deep and made of copper or plastic functions as a heat exchanger within the de-iced and dried surface. The length of pipes per square metre is approximately 5 to 7 m. The inner diameter usually is 16 to 25 mm and the flow rate ranges between a few to a dozen litres per minute, depending on the inlet temperature and climatic conditions. The result obtained also depends on the character of the road. Water (temperature 32 °C and the same flow rate) emits different thermal streams: for asphalt roads 90 W/m^2; for macadam 120 W/m^2; and for concrete 150 W/m^2 (Ragnersson 1997). The temperature drop (difference between temperature at the coil's inlet and outlet) depends on weather conditions and how intensely the equipment is working.

The technical, economic and working parameters of selected de-icing systems operating in different climatic and usage conditions vary considerably, especially as far as technical solutions and costs are concerned (Tables 1 and 2).

Considerably lower costs are given for de-icing systems operating in the USA. The yearly cost of exploitation and servicing of a system responsible for de-icing of a section of a road in Klamath Falls, Oregon was about 3800 US$. At the same time, the cost of sand treatment and ploughing of this section without de-icing was estimated at about 51 000 US$ yearly (Thurston et al. 1995).

In view of the above costs, the cheapest and most economic solutions may be instalments directly employing the heat of the Earth, e.g. from abandoned coal mines (see Heliasz, Ostaficzuk 2000) or waste heat.

POSSIBILITY OF USING WASTE HEAT FOR DE-ICING SYSTEMS

In industrial areas, huge quantities of heat are emitted through towers, coolers and sewage, or sent directly to the atmosphere. This heat can, however, be easily channelled and used in de-icing systems, which require low-temperature heaters, from a few degrees centigrade upwards).

ARTIFICIAL DE-ICING SYSTEMS IN POLAND - THE COST OF A SYSTEM BASED ON WASTE HEAT

The investment cost would be about 6 times lower in relation to the electrical system and 12 times lower in relation to the Gaia system (the cheapest one during exploitation.) The exploitation costs would be about 5.3 times lower in relation to the Gaia system and 16.6 times lower in relation to the electrical system for road heating (Tables 1 and 2).

It should be emphasised that there are efficient (although unintentional) de-icing, de-snowing and drying systems in some tens of Polish city agglomerations. In total, these systems may service roads a few thousand kilometres long and approximately 1.5 to over

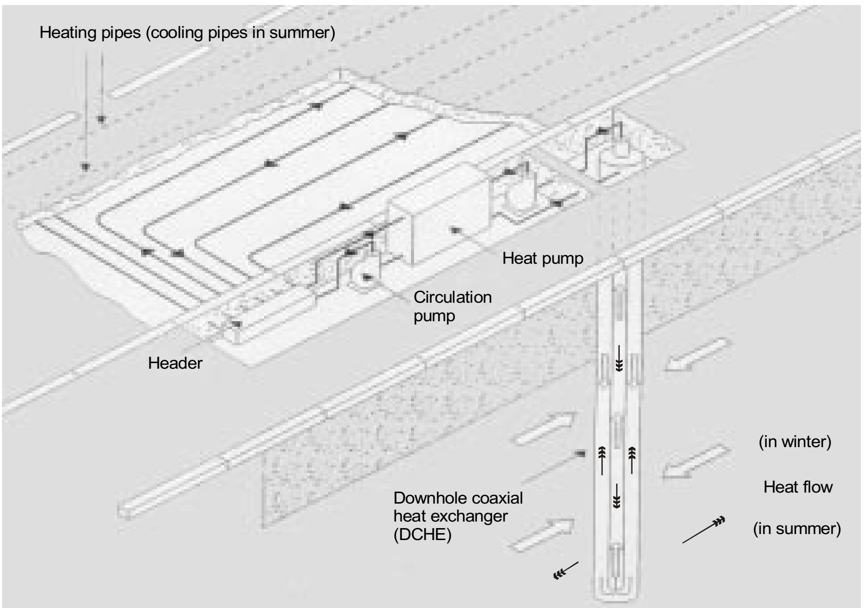

Fig. 2 Layout of the snow - melting system (after Morita 2000, with changes)
Ryc. 2. Schemat systemu odladzania (chłodzenia w lecie) wg. K. Morita ze zmianami.

Fig. 3. The oil boiler near the de-iced road
Ryc. 3. Bojler olejowy w pobliżu odladzanego odcinka drogi

5 m wide: these roads overlap with heat pipelines in municipal district heating systems. Heat lost from the pipelines distributing hot water from district heating systems to the local centres is used as a heating agent. Due to the insufficient insulation of the supply and return pipes, the ground around the pipeline is heated throughout the year. Thus the escaping heat is accumulated in a poor conductive man-made soil, from which it penetrates a narrow zone along the pipeline route on the surface. In winter the soil over the pipeline is so warm that snow melts and the surface of the terrain is dried immediately, largely during precipitation.

Winter temperature distribution under the ground surface above the pipeline (Kaliściak 1999, Topolski 1999) indicated that the heat stream was over 180 W/m^2 in the heating period and almost 80 W/m^2 afterwards when only hot hosehold water was distributed. Therefore, it should be a custom rule that the main heat lines are installed under pedestrian walkways for the benefit of those using the street.

DE-ICING SYSTEMS EMPLOYING THE HEAT OF COAL MINES

Considerable quantities of heat are expelled from coal mines with the ventilation air and discharge waters. The temperatures of waters pumped out from the mines are over 20 ^{o}C, and therefore can be used directly for road heating.

The demand of de-icing systems for heat power ranges between 150 and 250 W/m^2. This corresponds to a 5 ^{o}C drop of water temperature at a flow rate equal to 6 to 10 l/min in a coil 100 m long, heating about 15 m^2 of surface.In order to de-ice an area of 1000 m ^{2} it would be necessary to have a maximum flow rate of about 670 l/min (40 m^3/h, water temperature >15^{o}C).

Plastic pipes are safe in the case of a failure related to the cease of water flow during severe frost. Metal coils can be used as a stabilising component for prefabricated concrete construction elements for bridges and pavements. The reinforcement of construction elements with coils is an industrial standard in numerous countries, e.g. Switzerland (Pahud & Fromentin 1999, Laloui et al. 1999). In this concept heat is collected from the ground through pillars and continuous footing and used for supplying heat pumps during heating periods, and transmitted to the ground during cooling seasons.

Fig. 4. The control box and exhaust chimney connected to underground boiler of de-icing system
Ryc. 4. Urządzenia kontrolne i komin usuwający spaliny dla podziemnego bojlera zasilającego system odladzania

SOME PROSPECTIVE PLACES WHERE DE-ICING SYSTEMS CAN BE INSTALLED IN POLAND

The following are among the most suitable places where de-icing systems could be installed in Poland.

1) Selected road junctions on the A1 highway, the section between Sosnica and the Polish border, and selected sections of roads within city agglomerations in the Upper Silesian Coal Basin. The sources of heat are water from the mine dewatering system, waste heat from power stations situated close to the roads, and heat from the desalination plant in Debiensko. Provided the number of road accidents decreased by even 25%, the cost of such an instalment could be amortised within 2 to 3 years (having assumed average costs for a damaged car, absence from work, cost of medical treatment, damages equal to

Fig. 5. The passage for pedestrians destroyed by salt activity
Ryc. 5. Kładka dla pieszych zniszczona wskutek działania soli

50 000 zlotys). Bearing in mind the above and also taking into consideration the cost of the premature repair of overpasses, the costs of traffic problems in the key areas of the city make it obvious that de-icing systems should be installed where the supporting structures are threatened by salt activity (Fig. 5). In summer heat will be removed from the sun-heated road surface, and stored in underground waters (Fig. 2). This process will help to prevent the formation of the dangerous ruts that are caused by heavy trucks driving on asphalt in hot weather. Experience indicates (Morita 2000, Sanner & Knoblich 1999, Seiwald et al. 1999) that with this method heat reserves can be restored in underground waters and maintained until even the next heating period.

2) <u>The Silesian football stadium</u>. The source of heat would be mine waters from the coal mine supplied through the shafts not far from the central part of the stadium. It would be necessary to use 56 000 running metres of coil and 70 m^3/h water at an inlet temperature of 15 to 20 °C to cover the whole area of the stadium (about 8000 m^2). Geothermal de-icing systems are commonly used for stadiums in Iceland. In the case of the Silesian stadium in Chorzów the exploitation costs could be minimised as the heat energy of the mine waters would be delivered by the circulation pumps only.

3) <u>Parking in front of the Unia Oświęcim sports centre</u>. The source of heat would be waste waters from the desalination of discharge waters in the Industrial Centres Dwory. If only 10% of the planned potential was desalinated at the first stage (2.5 million m^3 discharge waters at 40 °C), an area of over 5000 m^2 could be kept dry. Heat could also be used for the heating of swimming pools and sports halls, as well as for the drying of stadiums and for the needs of the numerous fish farms near Oswiecim. The significant problem of extra waste heat from desalination plants in the summer months can be solved through the storage of warm waters in redundant mine workings. The problem of heat storage underground is now under intense research in Germany (Sanner & Knobloch 1999, Seiwald et al. 1999).

4) <u>One or two streets in Zakopane</u>, running down from Witkiewicza Street towards Cicha Woda/Zakopianka Road. In the most favourable scenario, Krupówki Street and later on Jagiellonska Street and Chramcówki Street could be involved. The source of heat would be water from the Antalówka intake, or more precisely, discharge waters from the swimming pool, and waters taken directly from the Zakopane well. As a minimum, 1500 m^2 of surface could be de-iced (i.e. a road 6 m wide and 250 m long or a pavement 2 m wide and 750 m long) at a flow rate of 20 m^3/h and water temperature of 22 °C. As a maximum, under the optimum scenario, when the flow rate was 60 m^3/h, these values would be tripled: 4500 m^2 of de-iced surface (corresponding to a road 6 m wide and 750 m long or over 2 km of 2-m-wide pavement).

5) <u>Golf-course between the Czerniaków Lake and Siekierki in Warsaw.</u> The golf-course near the Czerniaków Lake, Warsaw with numerous old river beds, canals and forest stands reaching as far as the Vistula meander in Siekierki, covers an area of a few square kilometres. There are different schemes for final landuse of this area. One is to construct a golf course there (Pininska 1966). The idea of having a golf course near the city centre, and near the district heating plant, appears very attractive. The vegetation would be preserved, and it would be an interesting and unique solution to have a golf course (Campbell 1994) with heated greens, teeing areas, bunkers and fairways; the golf course could be open all year round, and would become a recreation feature. No devastation of natural green scenery or building development would be permitted there. The source of heat energy would be waters (at about 20 °C) discharged from the nearby district heating plant through an open canal to the River Vistula (thousands of cubic metres per hour). It has been estimated that 120 000 m^2 of terrain could be heated (i.e. a road 6 km long and 20 m wide) by only 1000 m^3 of such water with a temperature drop equal to 5 °C. The engineering-geological conditions are very favourable for the instalment of coils there. After heat recuperation, water would be directed back to the canal and discharged to the river Vistula.

6) <u>Road bridges between Sosnowiec and Będzin.</u> Heat energy is available in cooler waters from the nearby district heating plant in Bedzin and the local coal mine (accessible from the district heating plant). The bridge is located at the lowermost point of a busy four-lane road. Owing to its location between two hills the overpass cools easily, which causes numerous hazards and difficulties for cars in late autumn and winter. Salt treatment results in the corrosion of cars and hence the necessity to have them repaired more frequently.

CONCLUSIONS

The de-icing of surfaces using of various forms of waste heat could be profitable, and the saved money spent on repairing roads, lowering of fuel consumption and prolonging the life of construction elements of bridges, roads and vehicles. The safety of car travel would be significantly increased in places liable to accidents in unfavourable weather conditions. Another advantage would be reduced costs of damage, post-accident medical treatment and vehicle repairs.

Other advantages are equally significant: pedestrian passages, pavements and walk lanes in city centres would be much more comfortable and the ground would not be contaminated with the salt solution that is used for the removal of the thawing snow.

De-icing systems are especially suitable for industrial agglomerations where great quantities of waste heat are available. The promotion of de-icing systems may involve modifications in the prefabricated-structure industry, to produce elements such as concrete plates that can be equipped with heat coils to be used with heat when necessary.

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